PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 : H04B 7/005

A1

(11) International Publication Number: WO 00/25444

(43) International Publication Date: 4 May 2000 (04.05.00)

(21) International Application Number: PCT/GB99/03496

(22) International Filing Date: 27 October 1999 (27.10.99)

(30) Priority Data:
9823396.8 27 October 1998 (27.10.98) GB

(71) Applicant (*for all designated States except US*): ROKE MANOR RESEARCH LIMITED [GB/GB]; Roke Manor, Old Salisbury Lane, Romsey, Hants SO51 0ZN (GB).

(72) Inventor; and
(75) Inventor/Applicant (*for US only*): HULBERT, Anthony, Peter [GB/GB]; 48 Wilton Crescent, Shirley, Southampton, Hants SO15 7QH (GB).

(74) Agent: KAY, Ross, Marcel; Siemens Shared Services Limited, Intellectual Property Department, Siemens House, Oldbury, Bracknell, Berkshire RG12 8FZ (GB).

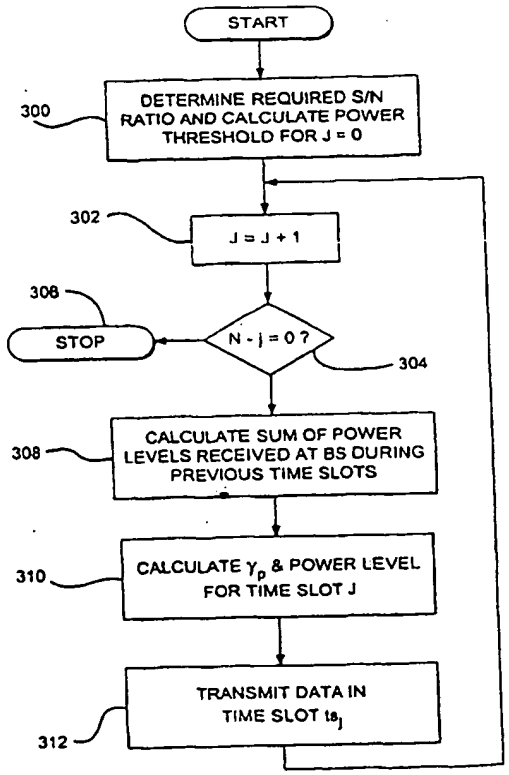
(81) Designated States: CN, JP, US, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.

(54) Title: METHOD OF AND APPARATUS FOR POWER CONTROL

(57) Abstract

When transmitting bursty data, for example packet data, a mobile terminal uses information relating to signal strength at the base station to determine the power at which the mobile terminal must transmit in order to produce a required signal to noise ratio at the base station. In frequency division duplex techniques, multi-path fading on the down-link is uncorrelated with multi-path fading on the up-link. Power measurements can be averaged at the mobile terminal over a likely fading period. However, this does not cater for instantaneous power level fluctuations in the up-link direction, which can result in the power transmitted by the mobile terminal being too high or too low at the start of a frame. The invention maintains a predetermined signal to noise ratio. At a given time slot, a power level is determined which, over remaining time slots, is based on the sum of power levels corresponding to previous time slots and the number of time slots remaining in the frame. Where multi-path fading occurs, smaller variations in average power over the frame will occur leading to improved system capacity.



FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania
AM	Armenia
AT	Austria
AU	Australia
AZ	Azerbaijan
BA	Bosnia and Herzegovina
BB	Barbados
BE	Belgium
BF	Burkina Faso
BG	Bulgaria
BJ	Benin
BR	Brazil
BY	Belarus
CA	Canada
CF	Central African Republic
CG	Congo
CH	Switzerland
CI	Côte d'Ivoire
CM	Cameroon
CN	China
CU	Cuba
CZ	Czech Republic
DE	Germany
DK	Denmark
EE	Estonia
ES	Spain
FI	Finland
FR	France
GA	Gabon
GB	United Kingdom
GE	Georgia
GH	Ghana
GN	Guinea
GR	Greece
HU	Hungary
IE	Ireland
IL	Israel
IS	Iceland
IT	Italy
JP	Japan
KE	Kenya
KG	Kyrgyzstan
KP	Democratic People's Republic of Korea
KR	Republic of Korea
KZ	Kazakstan
LC	Saint Lucia
LI	Liechtenstein
LK	Sri Lanka
LR	Liberia
LS	Lesotho
LT	Lithuania
LU	Luxembourg
LV	Latvia
MC	Monaco
MD	Republic of Moldova
MG	Madagascar
MK	The former Yugoslav Republic of Macedonia
ML	Mali
MN	Mongolia
MR	Mauritania
MW	Malawi
MX	Mexico
NE	Niger
NL	Netherlands
NO	Norway
NZ	New Zealand
PL	Poland
PT	Portugal
RO	Romania
RU	Russian Federation
SD	Sudan
SE	Sweden
SG	Singapore
SI	Slovenia
SK	Slovakia
SN	Senegal
SZ	Swaziland
TD	Chad
TG	Togo
TJ	Tajikistan
TM	Turkmenistan
TR	Turkey
TT	Trinidad and Tobago
UA	Ukraine
UG	Uganda
US	United States of America
UZ	Uzbekistan
VN	Viet Nam
YU	Yugoslavia
ZW	Zimbabwe

METHOD OF AND APPARATUS FOR POWER CONTROL

The present invention relates to a method of and apparatus for power control, of the type used in a communication system, for example, in a spread-spectrum communication system, such as a Code Division Multiple Access (CDMA) communication system.

In a CDMA cellular communication system, power control is used to equalize signal to noise (S/N) ratios of the signals received at a base station from various mobile terminals. In the term 'signal to noise ratio', the term 'noise' is intended to include interference in the form of signals from other mobile terminals, as well as background noise.

A known technique involves measuring the S/N ratio in respect of signals received from a given mobile terminal over a measurement interval and comparing the measured S/N ratio against a desired threshold. If the measured S/N ratio exceeds the desired threshold, a binary 1 (or 0, depending upon the convention employed) is transmitted (within the plurality of signals transmitted from the base station) to the mobile terminal originating the given signal. If the measured S/N ratio is lower than the desired threshold, a binary 0 (or 1, depending upon the convention employed) is transmitted to the given mobile terminal. The mobile terminal, in turn, responds by reducing its transmission power by, for example, 1 dB if a 1 (or 0) is received or by increasing its power by 1 dB if a 0 (or 1) is received. In this way, the received S/N ratio is held approximately constant as path loss between the given mobile station and the base station varies and/or as the level of interference at the base station from other mobile terminals varies.

The above technique is effective in the transmission of continuous data where any transients associated with the initial setting of transmitter power at

the mobile terminal can be ignored. However, where individual bursts (frames) of data are transmitted, for example packet data, the mobile terminal must set its initial transmitter power according to a so-called open loop power control technique. In this technique, the base station signals to the mobile terminal(s) the power at which the base station is transmitting; this can be either the total power received or the power of a particular signal which the mobile(s) station is receiving, and the interference level at the base station. The mobile terminal measures the power level of the corresponding signal received from the base station and uses the signalled information, i.e. the information relating to signal strength at the base station, to determine the power at which the mobile terminal must transmit in order to produce a required S/N ratio at the base station. On average, this should be the correct power. However, in many CDMA systems the frequency used for transmission from the base station to the mobile terminal (down-link) is different from the frequency used for transmission from the mobile terminal to the base station (up-link). Such a scheme is known as a Frequency Division Duplex (FDD) technique. In an FDD technique, propagation of signals is non-reciprocal in the short term, for example, multi-path fading on the down-link is uncorrelated with multi-path fading on the up-link. This effect can be mitigated somewhat by averaging the power measurements at the mobile terminal over the likely fading period. However, this does not cater for the instantaneous path level fluctuations in the up-link direction, resulting in the power transmitted by the mobile terminal being too high or too low at the start of the frame.

In a typical CDMA system, Forward Error Correction (FEC) with interleaving is employed in order to mitigate the effects of fading and interference from other signals operating on the same frequency. If a known soft decision decoding technique is employed, the effect of the interleaving is to

make the probability of uncorrectable errors in an interleaved frame a function more of the average S/N ratio over the frame rather than, for example, the worst case S/N ratio. Consequently, if the S/N ratio at the start of a frame is too high, implementation of power control reduces the S/N ratio to the required threshold by the end of the frame, but the overall average will be higher than necessary. Conversely, if the S/N ratio at the start of a frame is too low, implementation of power control increases the S/N ratio to the required threshold by the end of the frame, but the overall average will be lower than necessary.

It is therefore an object of the present invention to obviate or at least mitigate the above described disadvantages.

According to the present invention, there is provided a method of power control in a communications system capable of transmitting a frame having a plurality of time intervals, the method comprising the steps of: selecting a time interval in respect of which a power level is to be determined; summing any previously measured power levels in respect of any time intervals preceding the selected time interval; determining the number of any remaining time intervals, and setting the power level in respect of the selected time interval based upon the sum of previously measured power levels and the number of remaining intervals in order to achieve a predetermined S/N ratio in respect of the frame.

Preferably, the power level is set during transmission of the frame in such a way as to tend to keep the received signal to noise averaged over the frame constant.

Thus, if the signal is received at a S/N ratio higher than necessary at the beginning of a frame, the method will ensure that the signal will be received at a level lower than the nominal S/N ratio by the end of the frame. Where multi-path fading occurs the use of this method will result in smaller variation in average power over the frame, leading to an improvement in system capacity.

This differs from known techniques which try to modify the power level within each time interval so as to substantially keep to the predetermined signal to noise ratio during each interval.

Preferably, the time interval is a time slot.

At least one embodiment of the invention will now be described by way of example, with reference to the accompanying drawings, in which:

FIGURE 1 is a schematic diagram of the entities used in a communications system,

FIGURE 2 is a schematic diagram of a frame used by the system of Figure 1, and

FIGURE 3 is a flowchart of a method constituting an embodiment of the present invention.

Referring to Figure 1, a CDMA system comprises at least one base station 102 supporting a cell 104, the base station 102 being arranged to communicate with a mobile terminal 106 over a radio-frequency (RF) interface 108 by transmitting a frame 200 of data (Figure 2). The frame 200 comprises N time slots $ts_0, \ldots, ts_{N-1}$.

In operation, the frame 200 is transmitted from the mobile terminal 106 to the base station 102, during which power control is achieved by N adjustments of power corresponding to N time slots in the frame 200.

Referring to Figure 3, a required average S/N ratio γ_d at the base station 102 over the duration of the frame 200 is initially determined and set (step 300). A power level is then set so that the average S/N ratio γ_d per time slot at the base station 102 will be substantially met (step 300).

A subsequent time slot, ts_j, for which the power level is to be adjusted, is then selected (step 302) and the number of any remaining time slots, N-j, is determined (step 304). If the number of time slots remaining, N-j, is zero, no

further power levels are set for the frame 200 (step 306). If, however, one or more time slots remain, the sum of respective measured power levels received at the base station 102 during previous time slots is calculated (step 308). The calculation can be generally expressed as: $\sum_{i=0}^{j-1}\gamma_i$, where γ_i is the S/N ratio received in the ith slot.

Using the sum of the measured power levels, the predetermined average S/N ratio γ_d and knowledge of the number of remaining time slots, a predicted S/N ratio, γ_p is then calculated (step 310) and the value of γ_p is used to calculate the power level at which the mobile terminal 106 transmits signals to the base station 102. The equation used to calculate the predicted S/N ratio γ_p is derived as follows.

The predicted S/N ratio γ_p is calculated based upon the assumption that a target, of the average S/N ratio, γ_d, across the frame 200, will be met if the calculated predicted S/N ratio γ_p is maintained throughout the remainder of the frame 200, thereby keeping the average S/N ratio γ_d substantially constant over the frame 200.

Since N-j power control intervals (time slots) remain in the frame 200 for which a power level is to be predicted, in order to satisfy the S/N ratio requirement of $N\gamma_d$ for the entire frame 200, the predicted S/N ratio γ_p for the remaining intervals, γ_p needs to satisfy the following equation:

$$\sum_{i=0}^{j-1}\gamma_i + (N-j)\gamma_p = N\gamma_d$$

Thus, the above equation is solved for γ_p and hence the predicted required power level (and therefore the next threshold) is calculated using the following equation:

$$\gamma_p = \frac{N\gamma_d - \sum_{i=0}^{j-1} \gamma_i}{N - j}$$

During the selected time slot, ts_j, the mobile terminal 106 transmits at the power level set (step 312) corresponding to the associated predicted S/N ratio γ_p.

A subsequent time slot is then selected (step 302) and the above-described procedure for calculating and setting power levels is repeated (steps 304 to 312).

Minor obvious modifications can be made within the normal ability of a skilled person to take account of non zero periods for measurement and for signalling within the power control sub-system.

Claims:

1. A method of power control in a communications system capable of transmitting a frame having a plurality of time intervals, the method comprising the steps of:

selecting a time interval in respect of which a power level is to be determined;

summing any previously measured power levels in respect of any time intervals preceding the selected time interval;

determining the number of any remaining time intervals; and

setting the power level in respect of the selected time interval based upon the sum of previously measured power levels and the number of remaining intervals so as to achieve a predetermined signal to noise ratio in respect of the frame.

2. A method according to Claim 1, wherein the power level setting step takes place during transmission of the frame.

3. A method according to Claim 1, wherein the power level setting step keeps the received signal to noise ratio averaged over the frame substantially constant.

4. A method according to Claim 1, wherein the time interval is a time slot.

5. A method according to Claim 1, wherein the communications system is a spread spectrum communications system.

6. A method according to Claim 5, wherein the spread spectrum communications system is a CDMA communications system.

7. A method according to Claim 6, wherein the power level setting step achieves a signal to noise ratio, γ_p, which is given by the formula:

$$\gamma_p = \frac{N\gamma_d - \sum_{i=0}^{j-1}\gamma_i}{N-j}$$

wherein γ_i is the S/N ratio received at the base station in the ith interval; $\sum_{i=0}^{j-1}\gamma_i$ is the sum of S/N ratios received corresponding to previous time intervals; and $N\gamma_d$ is the desired total S/N ratio sum over the frame.

8. A method substantially as hereinbefore described with reference to Figure 3.

Fig. 1

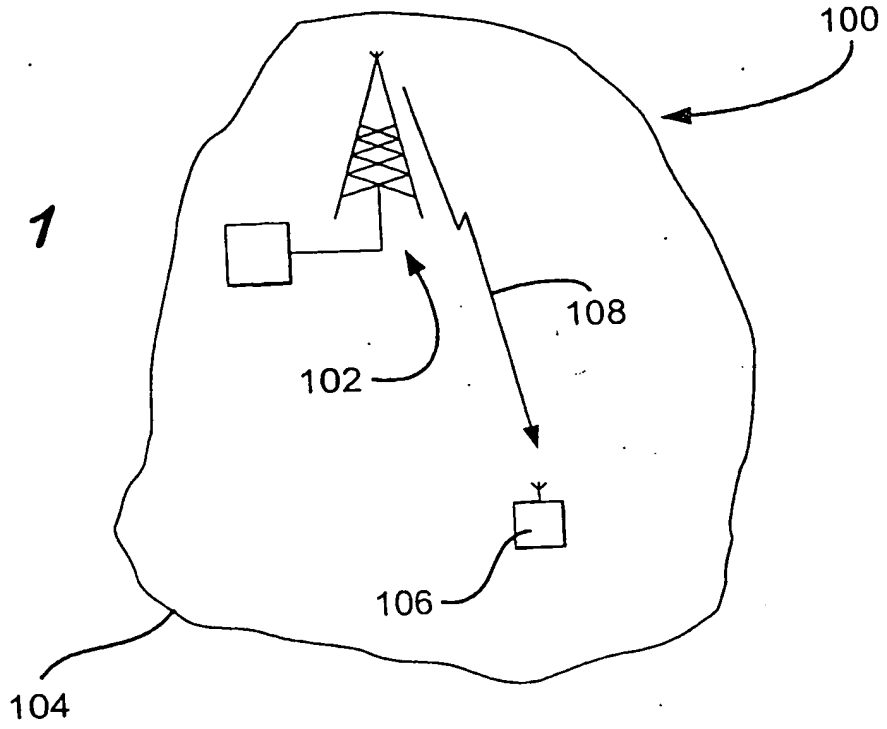


Fig. 2

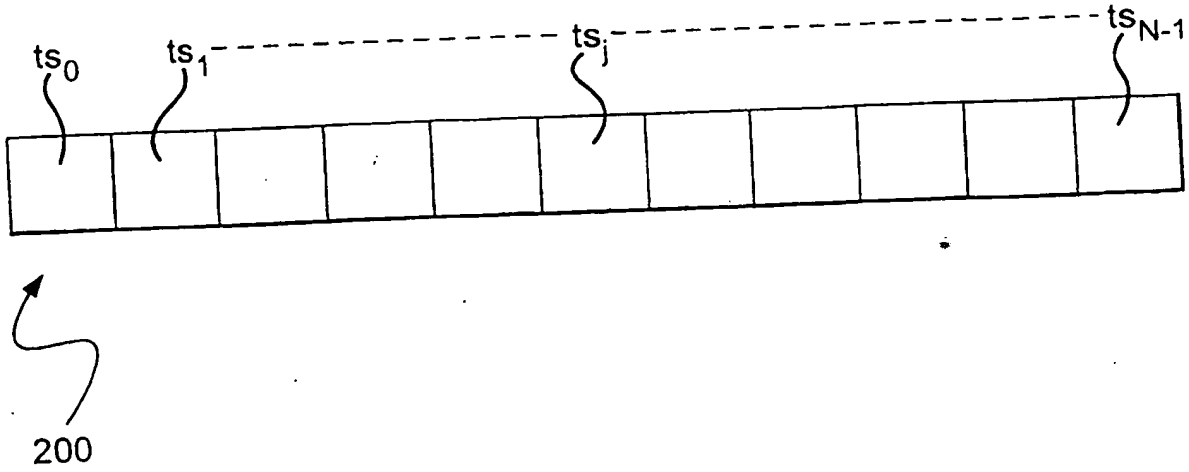
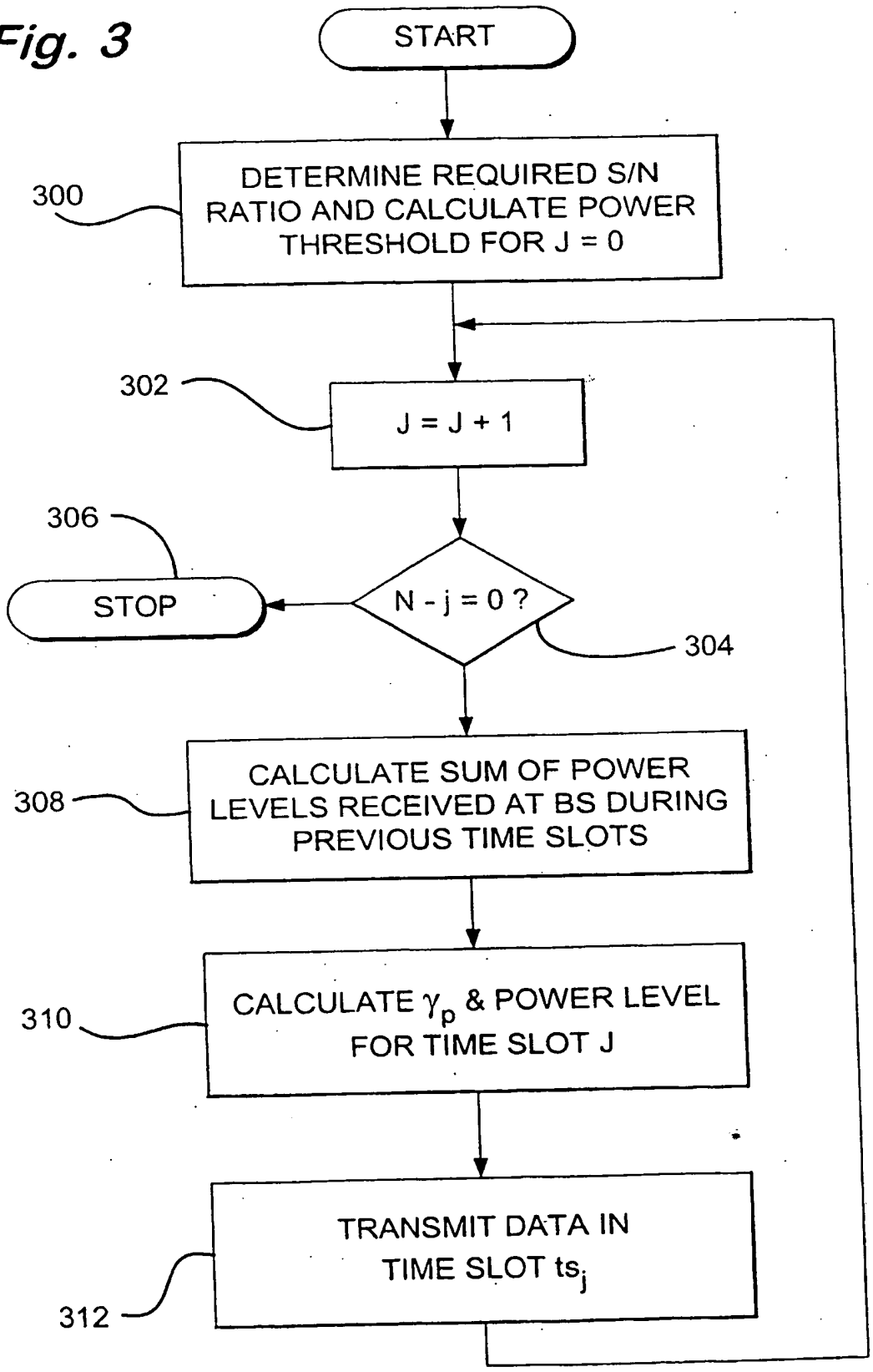


Fig. 3


START
DETERMINE REQUIRED S/N RATIO AND CALCULATE POWER THRESHOLD FOR J = 0
300
J = J + 1
302
N - j = 0 ?
304
STOP
306
CALCULATE SUM OF POWER LEVELS RECEIVED AT BS DURING PREVIOUS TIME SLOTS
308
CALCULATE γ_p & POWER LEVEL FOR TIME SLOT J
310
TRANSMIT DATA IN TIME SLOT ts_j
312

INTERNATIONAL SEARCH REPORT

Inter nal Application No
PCT/GB 99/03496

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04B7/005

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 305 468 A (BRUCKERT EUGENE J ET AL) 19 April 1994 (1994-04-19) abstract column 3, line 29 -column 5, line 56 claims 1-3 figures 5-7	1,8
A	WO 97 17769 A (MARTIN PAUL MAXWELL ;IONICA INT LTD (GB); GOODINGS RUPERT LESLIE A) 15 May 1997 (1997-05-15) page 1, line 13 -page 4, line 19 claims 1,2	1,8

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
17 December 1999	12/01/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Gkeli, M

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Inter nal Application No
PCT/GB 99/03496

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 810 743 A (NIPPON ELECTRIC CO) 3 December 1997 (1997-12-03) column 1, line 42 -column 2, line 29 column 4, line 14 - line 59 column 6, line 46 -column 8, line 6 claim 1 figures 1-3 -----	1,8

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

Inter ...nal Application No
PCT/GB 99/03496

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5305468 A	19-04-1994	CA 2088720 A,C	19-09-1993
		KR 9608955 B	10-07-1996
WO 9717769 A	15-05-1997	AU 7501696 A	29-05-1997
		BR 9611481 A	02-02-1999
		EP 0860058 A	26-08-1998
EP 0810743 A	03-12-1997	JP 2785804 B	13-08-1998
		JP 9321699 A	12-12-1997
		AU 2368697 A	04-12-1997
		CA 2206365 A	30-11-1997
		CN 1167411 A	10-12-1997